OPIC
OFFICE DE LA PROPRIÉTÉ INTELLECTUELLE DU CANADA

CIPO
CANADIAN INTELLECTUAL PROPERTY OFFICE

(12) (19) (CA) **Demande-Application**

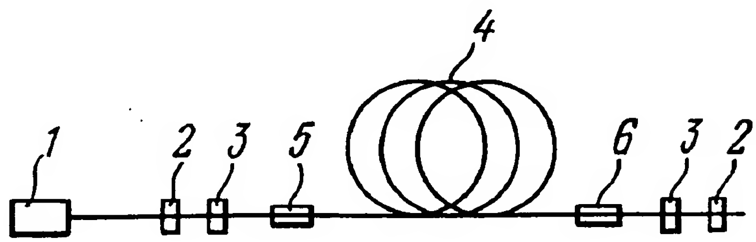
(21) (A1) **2,282,943**
(22) 1999/09/21
(43) 2000/03/22

(72) DIANOV, EVGENY MIKHAILOVICH, RU
(72) BUFETOF, IGOR ALEXEEVICH, RU
(72) GREKOV, MIKHAIL VLADIMIROVICH, RU
(72) KARPOV, VLADIMIR IVANOVICH, RU
(72) PROKHOROV, ALEXANDR MIKHAILOVICH, RU
(71) NAUCHNY TSENTR VOLOKONNOI OPTIKI PRI INSTITUTE OBSCHEI FIZIKI ROSSIISKOIAKADEMII NAUK, RU

(51) Int.Cl.[6] H04B 10/17
(30) 1998/09/22 (98117721) RU

(54) **LASER A FIBRE RAMAN**

(54) **RAMAN FIBER LASER**



(57) A Raman fiber laser comprises a laser as a pumping source whose light illuminates a fiber waveguide length having an oxide matrix which includes phosphorus oxide. The apparatus further comprises two pairs of fiber Bragg gratings which form distributed mirrors for a first and a second Stokes components resulting from the presence of phosphorus oxide, and long-period gratings for extracting light of first Stokes components resulting from the presence of silicon oxide and/or germanium oxide and generated by light of the pump laser and the first Stokes component resulting from the presence of phosphorus oxide. The long-period gratings provide an additional optical loss in the Stokes components to prevent resonance conversion of the pump light and the light of the first Stokes component resulting from the presence of phosphorus oxide into these Stokes components, thereby improving the efficiency of resonance conversion of the pump light into the second Stokes component resulting from the presence of phosphorus oxide.

ABSTRACT

A Raman fiber laser comprises a laser as a pumping source whose light illuminates a fiber waveguide length having an oxide matrix which includes phosphorus oxide. The apparatus further comprises two pairs of fiber Bragg gratings which form distributed mirrors for a first and a second Stokes components resulting from the presence of phosphorus oxide, and long-period gratings for extracting light of first Stokes components resulting from the presence of silicon oxide and/or germanium oxide and generated by light of the pump laser and the first Stokes component resulting from the presence of phosphorus oxide. The long-period gratings provide an additional optical loss in the Stokes components to prevent resonance conversion of the pump light and the light of the first Stokes component resulting from the presence of phosphorus oxide into these Stokes components, thereby improving the efficiency of resonance conversion of the pump light into the second Stokes component resulting from the presence of phosphorus oxide.

RAMAN FIBER LASER

Field of the Invention

The present invention pertains to laser technology and fiber optics and, more particularly, to a Raman fiber laser.

The invention is applicable to devices for pumping fiber signal amplifiers employed in broadband optical fiber communications systems to replace electronic repeaters, and may be also used as an optic signal amplifier.

Background of the Invention

A conventional Raman fiber laser comprises a fiber waveguide length as an active medium, a pumping source made in the form of a laser, and optical members to provide a multiple pass of light along the fiber waveguide length. (S.G.Grubb, T.Strasser, W.Y.Cheung, W.A.Reed, T.Erdogan, P.J.Lemire, A.M.Vengsarkar, D.J.DiGiovanni, D.W.Peckham, B.H.Rockhey, High-Power 1.48μm Cascaded Raman Laser in Germano-silikate Fibers, Optical Ampl. and Their Appl., Davos, USA, 15-17 June, 1995, p.197-199). The Raman fiber laser lases at wavelength λ = 1.48 μm. A dopant is GeO_2. The pumping source is an ytterbium laser with a lasing wavelength of 1.117 μm. The Raman fiber laser comprises five pairs of fiber Bragg gratings as distributed mirrors for wavelengths of 1.175μm, 1.24μm, 1.31μm, 1.40μm and 1.48μm, the fiber Bragg gratings forming

respectively five resonators for a first, second, third, forth and fifth Stokes components of Raman scattering.

The problem with this laser is its relatively poor efficiency in converting the light into the fifth Stokes component.

Most closely approaching the present invention is a conventional Raman fiber laser comprising a fiber waveguide length as an active medium, the fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element; a pumping source made in the form of a laser, and optical members to provide a multiple pass through the fiber waveguide length of light of a Stokes component associated with phosphorus oxide (see, e.g. RF Patent 2095902).

The Raman fiber laser lases at wavelength $\lambda = 1.48\mu m$ and comprises two pairs of fiber Bragg gratings as distributed mirrors for wavelengths of $1.24\mu m$ and $1.48\mu m$, to form two resonators for a first and a second Stokes components of Raman scattering, respectively.

The prior art laser, however, suffers a relatively low efficiency in converting the light into the second Stokes component due to converting the pump light into a Stokes component resulting from the presence of the chemical element compound.

Summary of the Invention

It is an object of the present inventions to improve efficiency of conversion of the pump light into Stokes components.

The object of the invention is accomplished in a Raman fiber laser comprising a fiber waveguide length as an active medium, the fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element; a pumping source made in the form of a laser, and at least one pair of optical members to provide a multiple pass through the fiber waveguide length of light of at least a first Stokes component of six Stokes components resulting from the presence of phosphorus oxide, wherein in accordance with the invention the fiber waveguide length comprises a long-period grating to provide an additional optical loss in a Stokes component resulting from the presence of the chemical element compound.

The oxide matrix preferably includes a compound of a chemical element selected from the group consisting of Si, Ge, N, Ga, Al, Fe, F, Ti, B, Sn, Ba, Ta, Zr , Bi.

The long-period grating preferably provides an additional optical loss in a first Stokes component resulting from the presence of the chemical element compound.

The first pair of optical members preferably provides a multiple pass through the fiber waveguide length of light of a first Stokes component resulting from the presence of phosphorus oxide.

The second pair of optical members preferably provides a multiple pass through the fiber waveguide length of light of a second Stokes component resulting from the presence of phosphorus oxide.

It is preferable that the optical member that provides a multiple pass through the fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide, is a fiber Bragg grating.

It is also preferable that the optical member that provides a multiple pass through the fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide, is a coupler.

The object of the invention is also accomplished in a Raman fiber laser comprising a fiber waveguide length as an active medium, the fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element; a pumping source made in the form of a laser, and at least one pair of optical members to provide a multiple pass through the fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide, wherein in accordance with the invention the fiber waveguide length comprises a group consisting of a first, second, third, forth, fifth and sixth supplementary optical members to provide a multiple pass through the fiber waveguide length of light of a Stokes component resulting from the presence of the chemical element compound, at least a light spectrum of one Stokes component resulting from the presence of phosphorus oxide and a light spectrum of one Stokes component resulting from the presence of the chemical element compound being overlapped.

It is preferable that a first pair of the supplementary optical members provides a multiple pass through the fiber waveguide length of light of a

first Stokes component resulting from the presence of the chemical element compound; a second pair of the supplementary optical members provides a multiple pass through the fiber waveguide of light of a second Stokes component resulting from the presence of the chemical element compound; a third pair of the supplementary optical members provides a multiple pass through the fiber waveguide length of light of a third Stokes component resulting from the presence of chemical element compound; a forth pair of the supplementary optical members provides a multiple pass through the fiber waveguide length of light of a forth Stokes component resulting from the presence of the chemical element compound; a fifth pair of the supplementary optical members provides a multiple pass through the fiber waveguide length of light of a fifth Stokes component resulting from the presence of the chemical element compound; a sixth pair of the supplementary optical members provides a multiple pass through the fiber waveguide length of light of a sixth Stokes component resulting from the presence of the chemical element compound.

It is preferable that the optical member providing a multiple pass through the fiber waveguide length of light of the Stokes component resulting from the presence of phosphorus oxide is a fiber Bragg grating.

It is also preferable that the optical member providing a multiple pass through the fiber waveguide length of light of the Stokes component resulting from the presence of phosphorus oxide is a coupler.

The object of the invention is also accomplished in a Raman fiber laser comprising a fiber waveguide length as an active medium, the fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element; a pumping source made in the form of a laser having an active member, and at least one pair of optical members to provide a multiple pass through the fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide, wherein in accordance with the invention the active member of the laser contains ytterbium ions.

The object of the invention is also accomplished in a Raman fiber laser comprising a fiber waveguide length as an active medium, the fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element; a pumping source made in the form of a laser, the laser having an active member containing neodymium ions, and at least one pair of optical members to provide a multiple pass through the fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide, wherein in accordance with the invention the optical member is a coupler.

The object of the invention is also accomplished in a Raman fiber laser comprising a fiber waveguide length as an active medium, the fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element; a pumping source in the form of a laser having an active member, and one pair of optical

members to provide a multiple pass through the fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide, wherein in accordance with invention the active member of the laser comprises tetravalent chromium ions.

It is preferable that the active member of the laser used as the pumping source and containing tetravalent chromium ions has a crystal structure of forsterite (Mg_2SiO_4).

It is preferable that the active member of the laser used as the pumping source and containing tetravalent chromium ions has a crystal structure of calcium germanate.

Brief Description of the Drawings

The invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a schematic view of a first embodiment of a Raman fiber laser in accordance with the invention;

Fig.2 is a schematic view of a second embodiment of a Raman fiber laser in accordance with the invention;

Fig.3 is a schematic view of a third embodiment of a Raman fiber laser in accordance with the invention;

Fig.4 is a schematic view of a forth embodiment of a Raman fiber laser in accordance with the invention;

Fig.5 is a schematic view of a fifth embodiment of a Raman fiber laser in accordance with the invention;

Fig.6 is a schematic view of a Raman fiber amplifier in accordance with the invention.

Detailed Description of Preferred Embodiments

Referring to Fig.1, a Raman fiber laser comprises a laser 1 as a pumping source, two pairs of fiber Bragg gratings 2 and 3 which form distributed resonator mirrors for a first and a second Stokes components resulting from the presence of phosphorus oxide. The laser illuminates a fiber waveguide length 4 having an oxide matrix which includes phosphorus oxide. The apparatus further includes long-period gratings 5 and 6 for extracting light of first Stokes components resulting from the presence of silicon oxide and/or germanium oxide and generated by light of the pump laser and the first Stokes component resulting from the presence of phosphorus oxide. The long-period gratings 5 and 6 provide an additional optical loss in the aforementioned Stokes components to prevent resonance conversion of light of the pump and the first Stokes component resulting from the presence of phosphorus oxide into these Stokes components, thereby improving efficiency of resonance conversion of the pump light into the second Stokes component resulting from the presence of phosphorus oxide.

As shown in Fig.2, a second embodiment of a Raman fiber laser comprises a laser 1 as a pumping source which illuminates a fiber

waveguide length 4 having an oxide matrix which contains phosphorus oxide and silicon oxide, two pairs of fiber Bragg gratings 2 and 3 which form distributed resonator mirrors for a first and second Stokes components resulting from the presence of phosphorus oxide, and for a third and sixth Stokes components resulting from the presence of silicon oxide, four pairs of fiber Bragg gratings 7, 8, 9 and 10 which form distributed resonator mirrors for a first, second, forth and fifth Stokes components resulting from the presence of silicon oxide. Light spectra of the first and second Stokes components resulting from the presence of phosphorus oxide overlap light spectra of the third and sixth Stokes components resulting from the presence of silicon oxide, respectively. As the result, the efficiency of resonance Raman conversion of the pump light into light of the wavelengths usable in optical fiber communication lines is enhanced.

Referring to Fig.3, a third embodiment of a Raman fiber laser comprises a laser 1 as a pumping source to illuminate a waveguide 4. The apparatus also includes two pairs of fiber couplers 11 and 12 which form two annular resonators for a first and a second Stokes components resulting from the presence of phosphor oxide, and long-period gratings 5 and 6 to extract light of first Stokes components resulting from the presence of silicon oxide and/or germanium oxide and generated by light of the pumping laser and a first Stokes component resulting from the presence of phosphor oxide. By providing an additional optical loss in the Stokes

components, the long-period gratings 5 and 6 prevent resonance conversion of the pump light and the first Stokes component light resulting from the presence of phosphor oxide into Stokes components resulting from the presence of silicon oxide and/or germanium oxide, thereby improving the efficiency of resonance conversion of the pump light into the Stokes components resulting from the presence of phosphorus oxide.

As shown in Fig.4, a forth embodiment of a Raman fiber laser comprises a pumping laser 1, a light input device 13 for illuminating a fiber waveguide with light of the laser, and an annular resonator for a first Stokes component associated with the presence of phosphorus oxide. The annular resonator includes a fiber waveguide length 4, a long-period grating 6 and a pair of fiber couplers 12. In all other respects, the laser operates in the same manner as the embodiment shown in Fig.3.

Referring to Fig. 5, a fifth embodiment of a Raman fiber laser is a simplified embodiment of the laser shown in Fig.2. It comprises a pumping laser 1 and a light input device 13 for illuminating a fiber waveguide 4 with light of the laser. The device 13 is preferably employed when there is available a more long-wave pumping source 1 emitting at a wavelength coincident with a wavelength of one of the Stokes components. In this case the distributed mirrors for this and all preceding Stokes components are omitted from the circuit.

The apparatuses in accordance with the present invention can be employed as optical signal amplifiers at any wavelength coincident with

any of Stokes components resulting from the presence of phosphorus oxide or silicon oxide and/or germanium oxide. To this end, resonators for this and subsequent Stokes components, and/or members providing additional losses at this wavelength should be omitted from the circuit, while some device should be added to input a signal to be amplified into the apparatus and output the signal after it has been amplified.

Fig.6 shows an amplifier circuit for an optical signal at a wavelength coincident with a first Stokes component resulting from the presence of silicon oxide and/or germanium oxide and generated by a first Stokes component resulting from the presence of phosphorus oxide, which is obtained from a Raman laser presented in Fig.1. The apparatus comprises a pumping laser 1, a fiber waveguide length 4 having an oxide matrix which includes phosphorus oxide, one pair of fiber Bragg gratings 2 forming distributed resonator mirrors for a first Stokes component associated with phosphorus oxide, a long-period grating 5 to provide an additional optical loss in light of a first Stokes component resulting from the presence of silicon oxide and generated by light of the pumping laser. The long-period grating 5 prevents resonance conversion of the pump light into this Stokes component, thereby enhancing the efficiency of light resonance conversion into the first Stokes component resulting from the presence of phosphorus oxide. The apparatus further comprises a directional coupler 14 to combine the pump light and the signal being amplified in the active waveguide 4.

If the lasers in accordance with the invention (Figs.1 to 5) are employed to pump erbium amplifiers, the pumping source 1 can be a Nd^{3+} or Yb^{3+} ion laser (Figs.1 to 3), and a Cr^{4+} ion laser (Figs.4 and 5).

In the first embodiment of a Raman fiber laser (Fig.1), the pumping source 1 was a 3.5W fiber neodymium laser having a fiber waveguide 30m long with a core containing 0.5 wt. %Nd^{3+}. The fiber Bragg gratings 5 and 6 were fiber waveguide lengths 1m long with a core containing 21 mol.% $Ge0_2$, with the core refractive index modulated at a period of about 0.35μm to provide a maximum reflection at wavelengths of Stokes components, the modulation index being 8 x 10^{-4}. The long-period gratings 7 and 8 were made of a fiber waveguide length 1m long with a core containing 21 mol.% $Ge0_2$, with the core refractive index modulated at a period of about 250μm to provide maximum introduced losses at wavelengths of the aforementioned Stokes components, the modulation index being 8 x 10^{-4}. The reflection index of the "blind" gratings 5 and 6 at wavelengths of 1.24μm and 1.48μm, respectively, was 99%, while the reflection index of the output grating 6 at a wavelength of 1.48μm was 20%. The fiber waveguide length 4 was 1km long with a core containing 19 mol.% P_2O_5. The fiber waveguide of the neodymium laser 1 had a square cross-section of 150 x 150μm and a reflective polymer coating, while the fiber waveguide 4, the fiber waveguide of the long-period gratings 7 and 8 and the fiber waveguides of the Bragg gratings 5 and 6 were of standard

lateral dimensions. The above waveguides were produced by a conventional technology using a chemical vapor deposition method.

The laser lased at a wavelength of 1.48μm, while in the absence of the long-period gratings 7 and 8 the lasing at the wavelength of 1.48μm was not attained.

In the second embodiment of a Raman fiber laser (Fig.2), a pumping source 1 was a 3.5W fiber ytterbium laser having a fiber waveguide 30m long with a core containing 0.5wt.%Yb^{3+}. The fiber Bragg gratings 5 and 6 were fiber waveguide lengths 1m long with a core containing 21 mol.% GeO_2. The reflection index of the "blind" gratings 5 and 6 at wavelengths of 1.24μm and 1.48μm, respectively, was 99%, while the reflection index of the output grating 6 at a wavelength of 1.48μm was 20%. The fiber Bragg gratings 7, 8, 9 and 10 were fiber waveguide lengths 1m in length with a core containing 21 mol.% GeO_2. The reflection index of the "blind" gratings 7, 8, 9 and 10 at wavelengths of 1.12μm, 1.18μm, 1.31μm and 1.40μm, respectively, was 99%. The fiber waveguide length 4 was 1km long with a core containing 19 mol.% P_2O_5. The fiber waveguide of the ytterbium laser 1 had a square cross-section of 100 x 100μm and a reflective polymer coating, while the fiber waveguide 4 and the fiber waveguides of the Bragg gratings 5, 6, 7, 8, 9 and 10 had standard lateral dimensions. The waveguides were produced by a conventional technology using a chemical vapor deposition method.

The laser lased at a wavelength of 1.48μm, while in the absence of the long-period gratings 7 to 10 the lasing at the wavelength of 1.48μm was not attained.

In the third embodiment of a Raman fiber laser (Fig.3), the pumping source 1 was a 3.5W fiber neodymium laser having a fiber waveguide 30m long with a core containing 0.5wt.% Nd^{3+}. Couplers 11 designed for wavelengths of 1.06μm/1.48μm were made from a conventional communications waveguide with a core containing 7 mol.% $Ge0_2$. Couplers 12 designed for wavelengths of 1.24μm/1.48μm were made from a conventional communications waveguide with a core containing 7 mol.% $Ge0_2$. Long-period gratings 7 and 8 were made from a fiber waveguide length 1m long with a core containing 21 mol.% $Ge0_2$.

The laser lased at a wavelength of 1.48μm, while in the absence of the long-period gratings 7 and 8 the lasing at the wavelength of 1.48μm was not attained.

In the forth embodiment a Raman fiber laser (Fig.4), the pumping source 1 was a 1.5W Cr^{4+}ion-activated fosterite crystal laser emitting at a wavelength of 1.24 μm. Couplers 12 designed for wavelengths of 1.24μm/1.48μm were made from a conventional communications waveguide with a core containing 7 mol.% $Ge0_2$. The long-period grating 8 was formed from a fiber waveguide length 1m long with a core containing 21 mol.% $Ge0_2$.

The laser lased at a wavelength of 1.48μm, while in the absence of the long-period grating 8 the lasing at the wavelength of 1.48μm was not attained.

In the fifth embodiment of a Raman fiber laser (Fig.5), the pumping source 1 was a 1.5W Cr^{4+}ion-activated calcium germanate crystal laser. The fiber Bragg gratings 6, 9 and 10 were fiber waveguide lengths 1m long with a core containing 21 mol.% GeO_2. The reflection index of the "blind" gratings 6, 9 and 10 at wavelengths of 1.31μm, 1.40μm and 1.48μm, respectively, was 99%, while the reflection index of the output grating 6 at a wavelength of 1.48μm was 20%. The fiber waveguide length 4 was 1km long with a core containing 19 mol.% P_2O_5.

The laser lased at a wavelength of 1.48μm, while in the absence of the long-period gratings 8, 10 the lasing at the wavelength of 1.48μm was not attained.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A Raman fiber laser comprising:

a fiber waveguide length as an active medium, said fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element,

wherein said fiber waveguide length comprises a long-period grating to provide an additional optical loss in at least a first Stokes component of six Stokes components, said first Stokes component resulting from the presence of said chemical element compound,

a pumping source made in the form of a laser,

at least one pair of optical members to provide a multiple pass through said fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide.

2. A laser as set forth in claim 1, wherein said oxide matrix includes a compound of a chemical element selected from the group consisting of Si, Ge, N, Ga, Al, Fe, F, Ti, B, Sn, Ba, Ta, Zr, Bi.

3. A laser as set forth in claim 1, wherein said first pair of optical members provides a multiple pass through said fiber waveguide length of light of a first Stokes component resulting from the presence of phosphorus oxide.

4. A laser as set forth in claim 3, wherein said second pair of optical members provides a multiple pass through said fiber waveguide length of

light of a second Stokes component resulting from the presence of phosphorus oxide.

5. A laser as set forth in claim 1, wherein said optical member providing a multiple pass through said fiber waveguide length of said Stokes component light is a fiber Bragg grating.

6. A laser as set forth in claim 1, wherein said optical member providing a multiple pass through said fiber waveguide length of said Stokes component light is a coupler.

7. A Raman fiber laser comprising:

a fiber waveguide length as an active medium, said fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element,

a pumping source made in the form of a laser,

at least one pair of optical members to provide a multiple pass through the fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide,

wherein said fiber waveguide length comprises at least one pair of supplementary optical members to provide a multiple pass through said fiber waveguide length of said light of a Stokes component resulting from the presence of said chemical element compound, at least a light spectrum of one said Stokes component resulting from the presence of phosphorus oxide and a light spectrum of one said Stokes component resulting from the presence of said chemical element compound being overlapped.

8. A laser as set forth in claim 7, wherein said first pair of supplementary optical members provides a multiple pass through said fiber waveguide length of light of said first Stokes component resulting from the presence of said chemical element compound.

9. A laser as set forth in claim 8, wherein said second pair of supplementary optical members provides a multiple pass through said fiber waveguide length of light of said second Stokes component resulting from the presence of said chemical element compound.

10. A laser as set forth in claim 9, wherein said third pair of supplementary optical members provides a multiple pass through said fiber waveguide length of light of said third Stokes component resulting from the presence of said chemical element compound.

11. A laser as set forth in claim 10, wherein said forth pair of supplementary optical members provides a multiple pass through said fiber waveguide length of light of said forth Stokes component resulting from the presence of said chemical element compound.

12. A laser as set forth in claim 11, wherein said fifth pair of supplementary optical members provides a multiple pass through said fiber waveguide length of light of said fifth Stokes component resulting from the presence of said chemical element compound.

13. A laser as set forth in claim 12, wherein said sixth pair of supplementary optical members provides a multiple pass through the fiber

waveguide length of light of said sixth Stokes component resulting from the presence of said chemical element compound.

14. A Raman fiber laser comprising:

a fiber waveguide length as an active medium, said fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element,

a pumping source made in the form of a laser having an active member which contains ytterbium ions,

at least one pair of optical members to provide a multiple pass through said fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide.

15. A Raman fiber laser comprising:

a fiber waveguide length as an active medium, said fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element,

a pumping source made in the form of a laser, said laser having an active member which contains neodymium ions,

at least one pair of optical members to provide a multiple pass through said fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide,

wherein said optical member is a coupler.

16. A Raman fiber laser comprising:

a fiber waveguide length as an active medium, said fiber waveguide length having an oxide matrix which includes phosphorus oxide and a compound of at least one more chemical element,

a pumping source made in the form of a laser having an active member which contains tetravalent chromium ions,

one pair of optical members to provide a multiple pass through said fiber waveguide length of light of a Stokes component resulting from the presence of phosphorus oxide.

17. A laser as set forth in claim 16, wherein said active member of the laser has a crystal structure of forsterite (Mg_2SiO_4)

18. A laser as set forth in claim 17, wherein said active member of the laser has a crystal structure of calcium germanate.

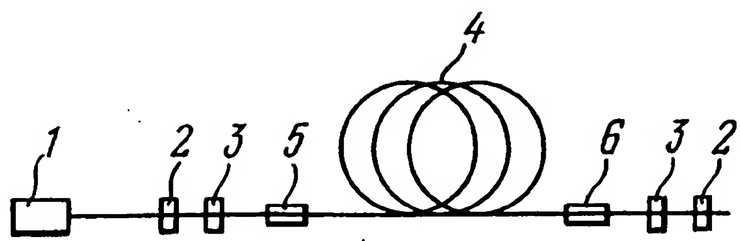


FIG.1

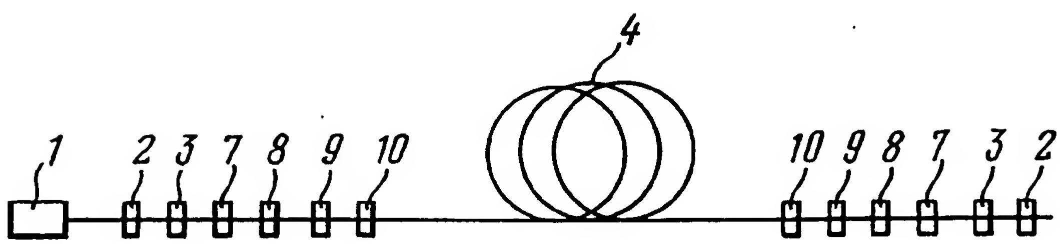


FIG.2

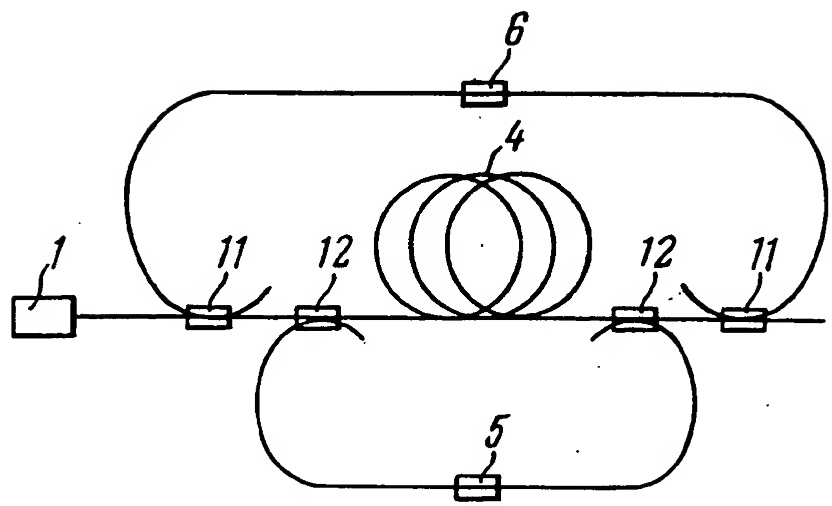


FIG.3

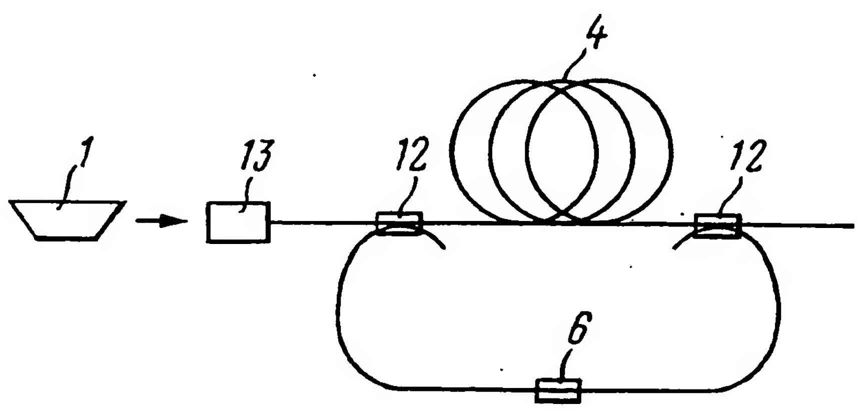


FIG.4

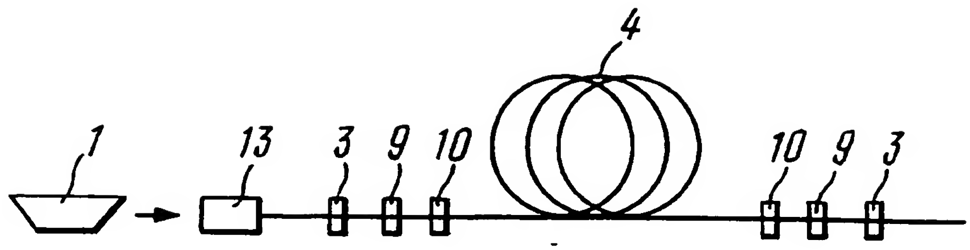


FIG. 5

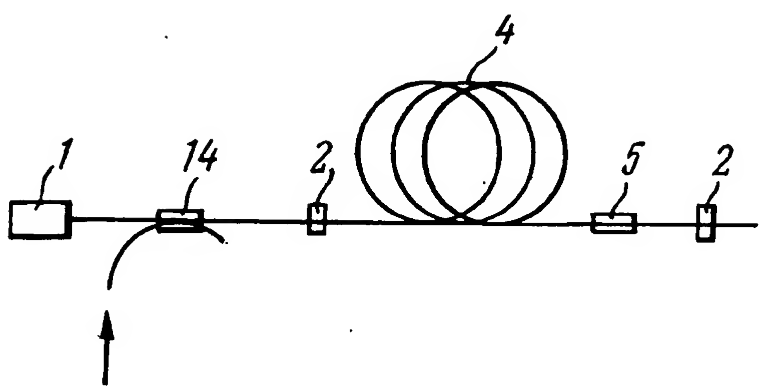


FIG. 6